PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION

ALASKA OREGON WASHINGTON

· · USDA FOREST SERVICE RESEARCH NOTE

PNW-141 February 1971

FIFTY-FIVE-YEAR-OLD LODGEPOLE PINE RESPONDS TO THINNING

by

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Abstract

Diameter growth of 55-year-old lodgepole pine trees released by thinning was substantially greater than unreleased trees in relative terms. Presumed release effect was sufficient to prevent a significant volume increment loss on thinned plots. However, absolute diameter growth was small because diameter growth capability of 55-year-old lodgepole pine trees is limited.

Keywords: Forest thinning, Pinus contorta, *lodgepole pine, tree growth, stand increment estimates, tree diseases, Pringle Falls Experimental Forest, Oreg.*

Harvested wood from lodgepole pine (*Pinus contorta*)[1] forests is only a small fraction of the total wood grown by these forests.

In most instances, more wood from wild stands is lost on trees that fail to reach usable size than is harvested. Natural stands growing on average sites on the Deschutes National Forest frequently yield 5,000 to 6,000 board feet per acre at age 100 years. However, these sites are capable of producing 6,000 to 7,000 cubic feet of wood in 100 years (Dahms 1964). Thus, less than 1 board foot is

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[1] Authorities for common and scientific names of trees, grasses, and shrubs and herbs are Little (1953), Hitchcock and Chase (1950), and Kelsey and Dayton (1942).

actually harvested for each cubic foot of potential wood production. A program of timely thinnings, designed to capture a larger share of the potential yield and enhance stand vigor, should greatly increase production of usable lodgepole pine wood.

A thinning study installed in 1934 in a 55-year-old lodgepole pine stand on the Pringle Falls Experimental Forest, about 35 miles south of Bend, Oregon, provides us with an opportunity to look at total wood production and see what happens to it over a 32-year period. Even though stand density control was not begun soon enough for optimum results, it is possible to visualize what might have happened with earlier thinnings. Furthermore, as we start piecing together managed-stand performance from thinning studies in stands of various ages for an entire rotation, results from this study in an older stand probably will become increasingly valuable.

EXPERIMENTAL CONDITIONS

The *experiment* consists of three 1/2-acre plots. Two were thinned, one to a 12- by 12-foot average spacing and the other to 16 by 16 feet. The third was left as an unthinned control. The *site* is a level, low-lying, poorly drained area. Leading understory plants are bearberry (*Arctostaphylos urva-ursi*), Idaho fescue (*Festuca idahoensis*), strawberry (*Fragaria cunefolia*), and patches of lodgepole pine reproduction. The Wickiup soil found here is typical of poorly drained conditions. It usually supports climax lodgepole pine. Site index for the three plots averaged 57, slightly above average for central Oregon. (Site index represents average height of the five tallest trees per acre at index age 50 years (Dahms 1964).)

The *stand* is essentially even-aged, with an average of 55 years at the time the study was begun in 1934. A high percentage of all trees were infected with rust diseases. W. H. Beeman commented in his 1936 establishment report:[2]

> During the establishment of these plots it was difficult to pick out the healthiest trees because of the presence of fungus diseases throughout the stand. The most conspicuous rust was *Cronartium stalactiforme* [*Peridermium stalactiforme*] which formed a canker often extending almost the entire length of the bole. ... Another

[2] W. H. Beeman, Jr. First progress report on Pringle Falls lodgepole pine thinning plots numbered 11, 12, and 13. (Unpublished typewritten report on file at the Bend Silviculture Laboratory dated Apr. 1, 1936.)

rust occurring on most of the trees was western pine gall (*Cronartium harknesii* [*P. harknesii*]). Almost all dead trees and those lacking in vigor were infected by one or both of these diseases. Although the healthiest trees were left, 67 percent of these were attacked.

The *kind of thinning* done in 1934 was only briefly mentioned in Beeman's report. However, McKay, in his 1942 report, stated that leave trees had been chosen mainly on the basis of spacing with little regard for size or vigor.[3]

Plots were not entirely comparable at the start of the experiment. Initially, basal area, average diameter, and cubic volume were all somewhat greater on the plot later thinned to the 12- by 12-foot spacing (table 1). Similarly, all these measures indicate that the plot thinned to the 16- by 16-foot spacing had the least basal area and volume. Although these differences were real, it would be difficult to find three plots more closely alike.

Treatments are not replicated, and we have no measure of plot-to-plot difference not associated with treatment; nevertheless, the experiment does give us a good clue as to growth possibilities under management.

RELATION TO PAST WORK

Barrett (1961) reported a good response of individual tree growth to increased growing space during the first 22 years. Our period of observation extends another 10 years, and trends from one measurement period to another are examined.

Volume and volume increment results differ from those presented by Barrett because a different volume formula was used (see footnote 4, table 1). The new volume formula provides for complete comparability with that used in gross and net yield tables for lodgepole pine (Dahms 1964).

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[3] Donald F. McKay. First progress report on Pringle Falls plots 11, 12 and 13 — thinning in lodgepole pine. (Unpublished typewritten report on file at the Bend Silviculture Laboratory dated Mar. 31, 1942.)

Table 1.--*Statistics before thinning, after thinning, and 32 years later--per acre basis*[1]*--for lodgepole pine*

Stand age and treatment	Number of trees	Average d.b.h.[2]	Average height[3]	Stand density: Basal area	Stand density: Bole area[4]	Stand density: CCF[5]	Volume: Cubic[4]	Volume: Scribner[6]
		Inches	*Feet*	*Square feet*			*Cubic feet*	*Board feet*
55, before thinning:								
Thinned 16 by 16 feet	574	5.1	45	92.7	21,169	112	1,939	1,471
Thinned 12 by 12 feet	616	5.5	47	116.3	25,386	146	2,606	2,809
Unthinned	630	5.1	45	101.1	23,208	133	2,232	1,464
55, after thinning:								
Thinned 16 by 16 feet	164	6.7	50	42.6	8,729	50	992	782
Thinned 12 by 12 feet	298	6.6	50	78.1	16,211	91	1,906	2,646
Unthinned	630	5.1	45	101.1	23,208	133	2,232	1,464
87: Thinned 16 by 16 feet	110	10.8	68	74.2	12,587	71	2,268	9,660
Thinned 12 by 12 feet	198	10.0	67	113.7	21,051	112	3,484	12,978
Unthinned	364	6.9	54	108.1	22,920	121	2,967	7,552

1/ All statistics are for trees 2.6-inch d.b.h. and larger unless otherwise stated.

2/ The arithmetic average of all diameters.

3/ Height of the tree of average diameter as read from a height over diameter curve.

4/ Volume and bole area formulas were derived from 190 trees felled and measured for volume table purposes as a part of the gross and net yield table project. The three volume formulas used are:

a. Volume in cubic feet = $0.031 + 0.002589D^2H$ for D^2H values through 1,482,
b. Volume in cubic feet = $0.36 + 0.002366D^2H$ for D^2H values from 1,483-14,195,
c. Volume in cubic feet = $3.49 + 0.0021461D^2H$ for D^2H values of 14,196 and larger,

where D = diameter breast high outside bark and H = total height.

Total stem volume including stumps and tips is the quantity estimated by these equations.

The bole area formulas used are:

a. Bole area in square feet = $0.68 + 0.1591\ DH$ for DH values through 398.
b. Bole area in square feet = $4.82 + 0.1487\ DH$ for DH values of 399 and larger.

Total stem surface area inside bark including tips and stumps is the quantity estimated. This closely approximates stem cambium area.

5/ The formula crown competition factor (CCF) = $\frac{1}{A}\,[0.0192N + 0.0168\Sigma D + 0.0036\Sigma D^2]$ where A = plot area in acres, N = number of trees, and D = d.b.h. outside bark, was taken from Alexander, Tackle, and Dahms (1967).

6/ Board-foot volume is based on the Scribner table (Johnson 1952). All trees 8.6-inch d.b.h. and larger are included to a 5.0-inch top.

RESULTS

Diameter growth was fastest on the most heavily thinned (16- by 16-foot) plot and slowest on the unthinned one (table 2). During the 32-year period, growth of largest trees selected at the rate of 100 per acre ranged from 2.9 inches on the unthinned plot to 4.5 inches on the most heavily thinned area.

There was a strong tendency for diameter growth to slow with increasing age and for apparent thinning advantage to decrease with the passage of time (table 2). Although diameter growth was averaging less than 0.1 of an inch per year during the last period on all plots, a few healthy trees with good crowns were still growing 0.12 inch per year or better. These were trees that had not been infected with one of the rust diseases and that had good growing room provided through either thinning or natural death of nearby competitors.

There was almost no relationship between diameter and diameter growth during the 32-year period. The 100 largest trees per acre grew at about the same rate as all trees (table 2). Similarly, regressions of diameter growth on diameter calculated for each plot for each measurement period showed either no or only slight significant slope. Obviously, larger trees had grown more rapidly in the past, but by age 55 this relationship had disappeared.

Because of mortality and shifts in relative diameter, diameter growth of trees that survived through a given period, as shown in table 2, is not the same as average diameter increase obtained by subtracting the average beginning from the average ending diameter (table 1). For example, the 100 largest trees per acre in 1966 had averaged 0.14 inch per year, or 4.5 inches, during the preceding 32 years on the most heavily thinned plot. However, increase in average diameter of the 100 largest trees was only 3.6 inches during the same period.

Diameter distribution has been modified substantially by thinning (fig. 1). Many of the smaller trees died on the unthinned plot, but on the thinned plots they were removed more promptly and more completely. There was also a tendency for more trees of larger diameters to develop on the thinned plots.

Height of the leading trees on all plots was similar in 1966. However, height of the tree of average diameter increased much more rapidly on the thinned plots than on the unthinned one (table 1). The

Table 2.--*Periodic annual diameter growth*[1] *in thinned and unthinned lodgepole pine*

Period	Average 100 largest trees per acre			Average all trees		
	Thinned		Unthinned	Thinned		Unthinned
	16 by 16	12 by 12		16 by 16	12 by 12	
	- - - - - - *Inches* - - - - - -			- - - - - - *Inches* - - - - - -		
1935-39	0.19	0.12	0.10	0.19	0.13	0.08
1940-46	.18	.10	.08	.17	.11	.06
1947-51	.13	.10	.08	.12	.09	.06
1952-56	.15	.12	.09	.14	.11	.09
1957-61	.10	.08	.08	.10	.07	.06
1962-66	.08	.06	.07	.09	.06	.05
1935-66	.14	.10	.09	.14	.10	.08

[1] The diameter growth recorded here is averaged diameter increment for those trees that lived through the period in question. Included are ingrowth trees. Fewer trees are involved in the 1935-66 period than any of the others because it includes only those trees that lived through the entire period.

difference is explained by the many small trees on the unthinned plot pulling down the average diameter. Similarly the tree of average diameter was 5 feet taller after thinning than before on the most heavily thinned plot (table 1).

Height growth of the tallest trees closely approximated that predicted by site curves contained in the gross and net yield tables for lodgepole pine (Dahms 1964). Site index for the three plots as a group was 57.7 in 1934 and 57.0 in 1966.

Basal area increment showed a general downward trend with increasing age as might be expected (table 3). The brief reversal of this trend during the 1952-56 period evidently reflected significantly better than average growing conditions and paralleled a similar trend in volume increment during the same period.

Mortality offset nearly half of the gross basal area increment on the two thinned plots, but 89 percent was lost on the unthinned plot.

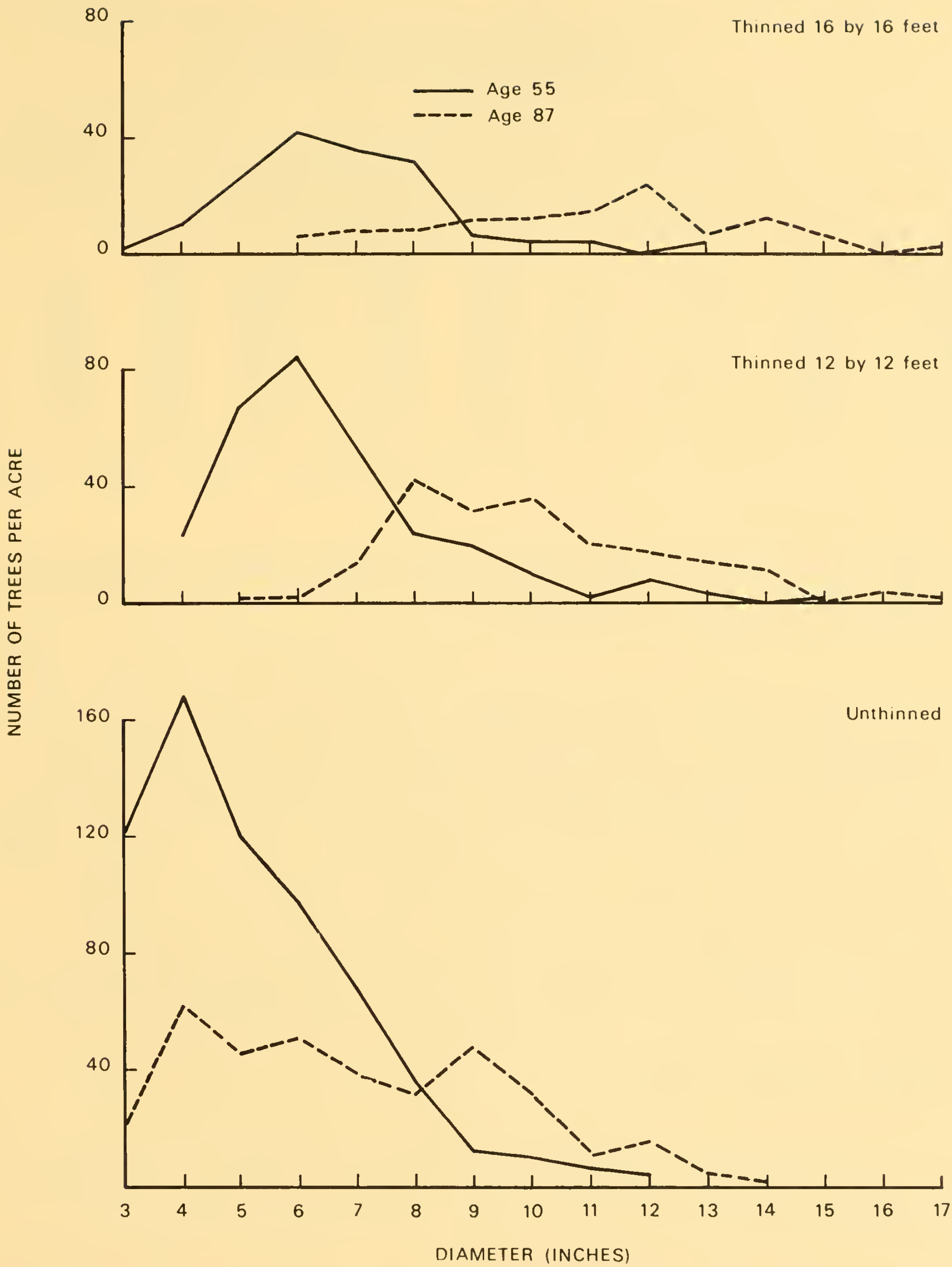

Figure 1.--*Diameter distribution immediately after thinning (age 55) and 32 years later (age 87).*

Table 3.--*Periodic annual gross and net basal area increment--per acre basis--for thinned and unthinned lodgepole pine*

Period	Thinned 16 by 16			Thinned 12 by 12			Unthinned		
	Net	Mortality	Gross	Net	Mortality	Gross	Net	Mortality	Gross
	Square feet								
1935-39	1.748	0.510	2.258	1.986	0.790	2.776	0.050	2.545	2.595
1940-46	.652	1.284	1.936	1.105	1.183	2.288	.231	1.794	2.025
1947-51	1.112	.482	1.594	1.236	.820	2.056	.748	1.259	2.007
1952-56	1.272	.494	1.766	1.041	1.358	2.399	.356	1.953	2.309
1957-61	1.201	.357	1.558	.315	1.224	1.539	.060	1.724	1.784
1962-66	.085	1.018	1.103	1.009	.245	1.254	.132	1.697	1.565
1935-66	.989	.728	1.717	1.115	.952	2.067	.218	1.827	2.045

Thus the thinning probably eliminated many of the trees most likely to die, but because not enough healthy trees were available to leave, substantial mortality continued.

Gross cubic volume increment may not have been greatly affected by thinning for the 32-year period as a whole (table 4). Volume production on the three plots ranked the same as prethinning volume and basal area. Consequently, production differences may primarily reflect prethinning plot differences and some uneven mortality that caused a large hole in the most heavily thinned plot. However, the fact that the plot thinned to 12 by 12 feet produced less than the unthinned plot during the first 5 years but surpassed production on the unthinned area during later periods suggests that thinning probably caused a temporary increment reduction. Although this experiment does not precisely define the relationship of volume increment to stand density, it does indicate that there was no large-scale thinning-caused growth reduction.

Gross cubic volume increment on the unthinned plot was very close to that estimated by the gross volume increment formula from the gross yield table (Dahms 1964). Actual performance was 8.7 percent above that predicted for the 32-year period on the unthinned plot. Because the increment formula was developed from natural stands, a prediction based on the unthinned density was the most meaningful. However, the estimate obtained for the unthinned stand was also close to that for the thinned plots.

Table 4.--*Periodic annual gross and net cubic volume increment--per acre basis--for thinned and unthinned lodgepole pine*

Period	Thinned 16 by 16			Thinned 12 by 12			Unthinned		
	Net	Mortality	Gross[1]	Net	Mortality	Gross[1]	Net	Mortality	Gross[1]
	Cubic feet								
1935-39	49.0	10.6	59.6	52.7	18.5	71.2	27.0	56.5	83.5
1940-46	27.4	30.9	58.3	39.9	27.9	67.8	23.4	40.8	64.2
1947-51	50.8	10.7	61.5	65.5	21.2	86.7	43.5	31.3	74.8
1952-56	54.6	12.9	67.5	65.6	35.2	100.8	30.6	48.4	79.0
1957-61	51.0	10.8	61.8	31.7	35.6	67.3	19.7	45.2	64.9
1962-66	11.9	31.4	43.3	43.4	6.2	49.6	-5.9	46.4	40.5
1935-66	39.9	18.7	58.6	49.2	24.3	73.5	23.1	44.5	67.6

[1] Includes a small amount of ingrowth.

Net cubic volume increment on the unthinned plot was only about half of that on the thinned plots. About two-thirds of the gross increment was lost to mortality on the unthinned area, compared with only about one-third on the thinned plots.

Net board-foot volume increment ranged from 190 board feet per acre annually on the unthinned plot to 323 on the moderately thinned one (12 by 12 feet) during the 32-year period[4] (table 5). Production averaged about half again as much on the thinned plots as on the unthinned area.

Growth of trees into board-foot size was the big source of increment at first. For example, number of trees with 8.6-inch d.b.h. (present minimum board-foot size) increased from 16 per acre in 1934 to 50 in 1939 on the heavily thinned plot.

Added wood on trees already of board-foot size and an increasing number of board feet per cubic foot with increasing tree size were the principal sources of board-foot increment during the latter part of the 32-year period. The following tabulation of board feet per

[4] The smallest usable tree on most lodgepole pine sales must produce some studs and is about 8.6-inch d.b.h. This has, been accepted as minimum usable, or board-foot, size for this publication. However, in some instances smaller trees are being chipped, but so far some larger trees must be included to make the operation economically possible.

Table 5.--*Periodic annual gross and net Scribner board-foot volume--per acre basis--for thinned and unthinned lodgepole pine*

Period	Thinned 16 by 16			Thinned 12 by 12			Unthinned		
	Net	Mortality	Gross	Net	Mortality	Gross	Net	Mortality	Gross
	Board feet								
1935-39	270	0	270	148	22	170	113	15	128
1940-46	263	57	320	242	0	242	150	18	168
1947-51	312	35	347	341	41	382	173	57	230
1952-56	399	31	430	507	26	533	173	49	222
1957-61	315	49	364	353	111	464	355	64	419
1962-66	113	145	258	380	0	380	194	84	278
1935-66	278	53	331	323	31	354	190	46	236

cubic foot by tree size illustrates how the more favorable ratio in larger trees can affect board-foot increment:

Tree diameter	*Board feet per cubic foot (1966)*
(Inches)	
9	3.21
10	3.72
11	4.13
12	4.48
13	4.77
14	5.02
15	5.23
16	5.42
17	5.59

Not all trees reached board-foot size. Even on the most heavily thinned plot only 88 out of 110 trees per acre had attained that size by 1966. Unevenly distributed mortality on this plot allowed overly dense groups to develop along with one large hole. Number and percent of total trees reaching board-foot size by treatment are:

Treatment	*Number*	*Percent*
Unthinned	112	31
Thinned 12 by 12 feet	138	70
Thinned 16 by 16 feet	88	80

Net mean annual board-foot increment ranged from 87 board feet per acre on the unthinned plot to 149 on the moderately thinned one at age 87 in 1966 (fig. 2). Because board-foot increment was just beginning at age 55, mean annual increment was low at that time but rising rapidly with increasing age.

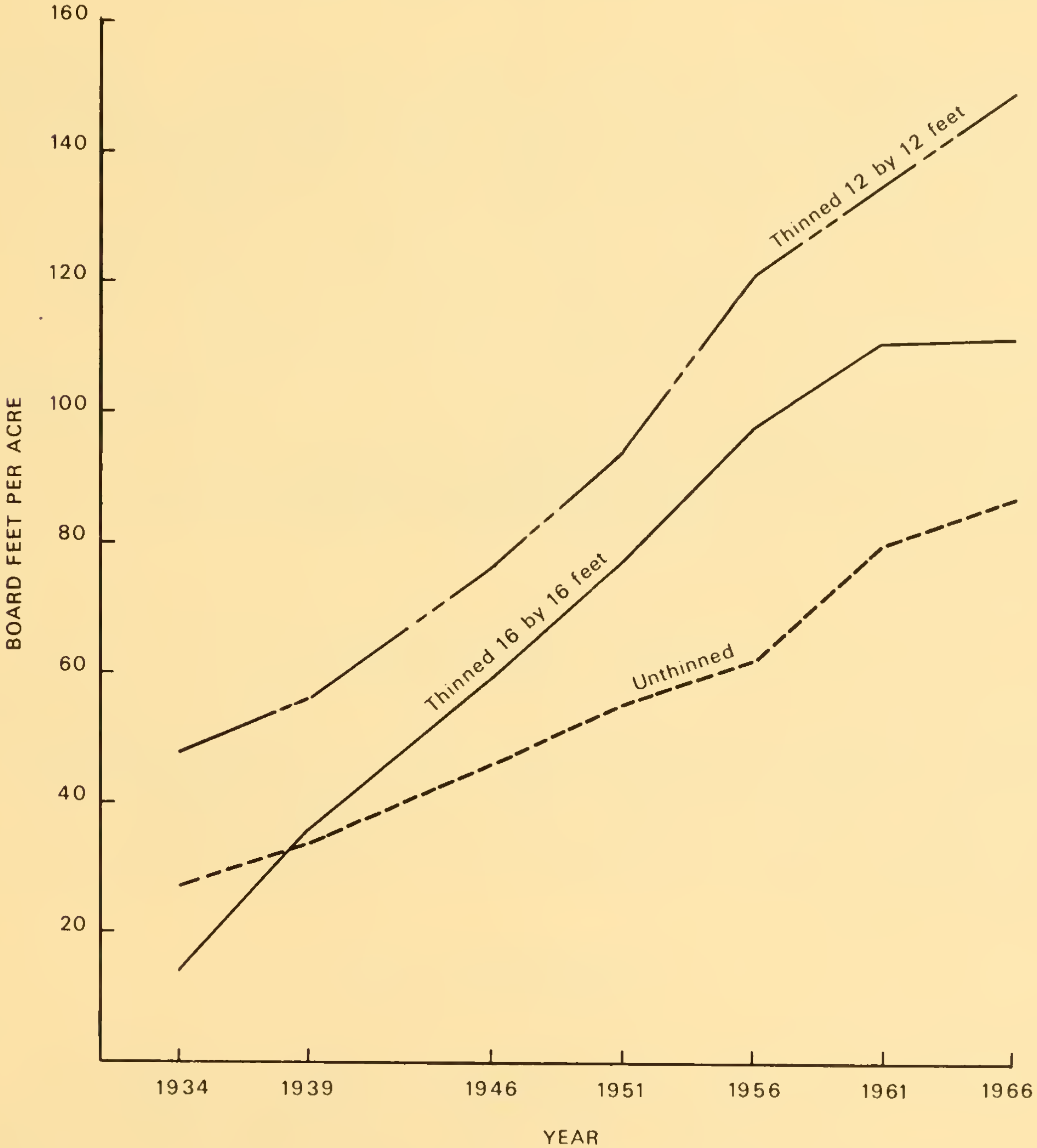

Figure 2.--*Mean annual net board-foot increment--per acre basis--for thinned and unthinned lodgepole pine.*

DISCUSSION

Board-foot, or usable, growth has been substantial during the 32 years after thinning. Net annual per acre volume increment on the two thinned plots averaged 300 board feet for the 32-year period, and mean annual per acre increment reached 130 at age 87. However, slowness of crop trees in reaching board-foot size and heavy mortality losses have dissipated a large portion of the potential usable wood production.

Rust-caused mortality was high on these plots. It accounted for approximately three-fourths of the total volume loss. The large number of infected trees, 67 percent after thinning, was the major reason. Even though this is a much higher than average percentage (Dahms (1965) reported 46.4 percent), wide distribution of cankers in lodgepole pine probably means there usually will be losses.

Thinning the 55-year-old stand achieved rather modest results. Although the apparent percentage increase in diameter growth from thinning was impressive, the advantage in absolute terms was not great. Undoubtedly, a considerable number of trees were "pulled into" the merchantable size class by the thinning. However, the large number of rust cankers and the consequent high mortality and poor vigor of many trees have cut short the growth period and minimized the advantages of thinning.

Net annual increment of approximately 300 board feet per acre during the 32 years after thinning is a positive factor. If a stand as old as 50 or 60 years is too dense to produce a usable harvest but the trees are healthy, a precommercial thinning could provide enough increase in diameter growth to pull a substantial number over the usable size threshold. The present study suggests health of the stand to be thinned is the key consideration in making the thinning decision for older stands.

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